Modelling of sperm motility in a microchannel.

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Project Outline and Objectives

Motility of an individual micro-organism can often be modelled as forward propulsion with constant speed and the biased random walk in swimming directions. When a population of micro-organisms is considered, variability in both forward speed and characteristics of angular orientation (degree of bias, angular diffusivity) must be accounted for.

In this project, propagation of sperm cells along a micro-channel will be modelled. A large population of cells with a given distribution of swimming characteristics will be "placed" at one end of a channel and the distribution at different locations along the channel will be computed. While the forward calculation is straightforward, reconstruction of the initial distribution of swimming characteristics from the time dependence of cell distribution at the "exit" will require solution of a parameter estimation problem which may be ill-conditioned.

We will start with a script (in MatLab) for the simulation of "forward" problem given a known probability distribution for the swimming characteristics. We will attempt to model cell motility in a still fluid and in the time-dependent viscoelastic flow along the micro-channel. As the second part of the project, you will attempt reconstruction of the initial distribution from snapshots of the simulated data. This is intended to mimic the experimentally observable distribution of cell characteristics at the "exit" of the channel. Ideally, you will assess the reconstruction error when the number of cells at "exit" end of the micro-channel is relatively small.

Required Background and Methodology

Basic programming skills - eg MatLab or C. Discrete event simulation. Basic statistical inference.

Research Outcomes

There is an experimental counterpart of the project, which will run in parallel at the School of Engineering and Centre for Human Reproductive Science in Birmingham. If the project is successful, you will have a chance to compare results and apply your methods to real experimental data.

PhD prospects

Rather than the popular concept of the 'sperm count', sperm motility is the most common cause of male subfertility. There are a number of gaps in our scientific understanding, and most significantly, biomedical research generally does not take into account the mechanical aspects of sperm motility, not least the thin, highly viscoelastic mucus films that sperm must traverse. Of the tens of millions of sperm that are inseminated, only thousands reach the fallopian tube, and only ten or so reach the egg. The roles of random dispersion, peristaltic flows, and possible chemical and thermal cues to guide sperm may all play a role in determining how the population spreads out, but the precise interplay of these factors is not understood.

The experimental study involving micro-channels will likely be continued as a joint programme between the School of Engineering at Warwick and the Schools of Mathematics and Medicine at The University of Birmingham where the CFD simulation for an individual cell is performed by Dr. David Smith. The programme would require further statistical modelling of sperm cell populations as well as CFD modelling of viscoelastic flows with moving boundaries which gives an excellent opportunity for a PhD project.

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